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EXTENSION BULLETIN No. 41

OBSERVATIONS ON RUST CONTROL

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FACTORS WHICH PREDISPOSE THE WHEAT CROP TO RUST

1. Late maturing varieties.
2. Rankness of growth on summerfallow.
3. Late seeding and delayed maturity.
4. Seeding too thin on rich soils, resulting in rank growth.
5. Weak seed.
6. Poor seed bed, uneven depth of seeding and uneven germination.
7. Harrowing growing grain.
8. Excessive and unbalanced manuring.
9. Drifting soil.
10. Poor drainage.
11. Open, uncompacted soils.
12. Soils too poor in fertility to complete the growth produced early in the season.
13. Damp, muggy, humid weather conditions; excessive moisture after grain has headed out or at time of infection.
14. Slow growing seasons.
15. Any factor which retards growth or produces softness or weakness of straw, or delays maturity, is a predisposing factor.

Observations on Rust Control

INTRODUCTION

Black stem rust of wheat (Puccinia graminis tritici) is one of the most important of the diseases of our western wheat fields. The loss to the Province of Manitoba in 1916 from this disease was very great. In 1917 the attack was again fairly severe, and in 1918, despite the dry weather, there was considerable rust in the crop. Consequently, the questions are being persistently asked: What is the cause of wheat rust, and what can be done to control it?

During the summer of 1916 the writer of this article was experimenting with some problems in soil and crop management and during the course of the season had several hundred plots under observation. The amount of rust on some of these plots and the lack of it on some others led the writer to believe there must be some conditions of soil management which result in making a crop more resistant to rust. This conclusion was suggested because of the fact that all the plots under investigation in the soil management experiments were sown with the same seed. The resulting variation in the damage from rust as shown in the threshed grain seemed to be directly chargeable to the cultural methods employed. As conclusions drawn from one season's crop cannot be taken as final, it was deemed advisable not to publish the same until after further observation. Close observation in 1917 and 1918 showed that the general conclusions drawn in 1916 regarding the effect of soil management on rust infection and damage to the wheat crop, were in the main correct and held good in all three years. We, therefore, submit a report of several cultural operations and their effect upon the amount of rust on wheat, together with some suggestions as to methods of decreasing to some extent the ravages of the disease in future years. If by following certain methods, or using certain precautions we lessen the damage done by wheat rust by only one bushel per acre, we shall in one year alone save the Province of Manitoba several millions of dollars.

The experiments quoted in this bulletin were conducted on a heavy clay soil, and while some of the conclusions drawn from them would not be applicable to some other types of soil in the Province yet they show that the crop can be so modified by soil management as to reduce the loss from black stem rust to an appreciable extent.

OBSERVATIONS ON THE EFFECT OF CULTURAL WORK ON BLACK STEM RUST IN WHEAT, AND SUGGESTED METHODS OF DECREASING THE DAMAGE . . . . . .

I—VARIETY RESISTANCE TO RUST

One of the first questions asked in regard to rust control is "which variety is the most resistant?" The following table shows the results obtained on the College Farm during the severe attack of rust in the season of 1916.

TABLE No. 1
Varieties of Wheat on Fallow, 1916

Yield per acre	Weight per bushel	Per acre Yield of straw	Rust on straw on basis of 100 points	Days maturing
bus. lbs.	lbs.	lbs.		
Pioneer . . 31 20	Pioneer . . . 56	Prelude . . . 3,000	Prelude . . . 25	Prelude . . 94
Marquis . 30 00	Prelude . . . 55	Pioneer . . . 4,320	Pioneer 29	Pioneer . . 95
Prelude . . 29 10	Marquis . . . 53	Marquis . 4,680	Marquis . . . 59	Marquis . 97
Red Fife . 22 40	Red Fife . . 49½	Garton's . . 5,200 (46)	Red Fife . . 59	Garton's . 98 (46)
Gartons . 22 20 (46)	Garton's . . 48 (46)	Minn. 169 5,620	Garton's . . 63 (46)	Red Fife . 99
Minn.169 20 00	Minn. 169 . 45½	Red Fife . . 5,700	Minn. 169 . 63	Minn. 169103

The above table shows the results with six different varieties of spring wheat grown on summer fallow. There is a distinct line of demarcation between the first three and the last three varieties in each column. Taking the weight per measured bushel as an indication of the amount of damage done, we find that the early maturing varieties did not suffer nearly so much as the later maturing varieties. It would appear from a study of the above table that damage by rust was not so much a matter of variety resistance, as early maturity. There seems to be a correlation of characters which is fairly constant. Early maturity, heavy grain and light straw are associated with little rust. Late maturity, light grain and heavy straw are associated with much rust. We find also that Pioneer and Prelude, which are usually considerably behind the heavier strawed and later maturing varieties in yield per acre, this year reversed their position, and Pioneer is at the head of the list with Prelude third. Marquis gave a higher yield than Prelude, but we notice that it weighed only fifty-three pounds per bushel, thus indicating that it was damaged more.

Close observation of these varieties re their susceptibility to rust in the two following seasons, 1917 and 1918, showed the same general ratio of damage, though not in so great a degree, and is recorded as follows:—

TABLE No. 2
Rust Observations on Varieties of Wheat, 1917

Amount of rust on straw on basis of 100 points	Weight of grain per measured bushel	Days maturing	Yield of straw per acre	Yield of grain per acre
	lbs.		lbs.	bus. lbs.
Prelude 10	Prelude . . . 62½	Prelude . . 87	Prelude . . 2840	Marquis . 41 30
Marquis 27	Pioneer . . . 62½	Pioneer . . 95	Pioneer . . 3620	Garton's . 39 20 (46)
Pioneer 30	Marquis . . . 62	Marquis . 97½	Marquis . 4160	Pioneer . . 37 20
Red Fife 50	Garton's . . 61	Garton's . 99	Red Fife . 4740	Minn. 37 00
Minn. 169 50	Red Fife . . 58½	Red Fife . 105	Garton's . 4780 (46)	Red Fife . 35 00
Garton's (46) . 60	Minn.169 . 56½	Minn.169 105	Minn.169 5320	Prelude . . 28 00

TABLE No. 3

Rust Observations on Varieties of Wheat, 1918

Amount of rust on straw on basis of 100 points	Weight of grain per measured bushel	Days maturing	Yield of straw per acre	Yield of grain per acre
	lbs.		lbs.	bus. lbs.
Pioneer......10	Pioneer ...65½	Prelude....114	Prelude..2740	Marquis .51 40
Prelude......15	Prelude...65¼	Pioneer....122	Pioneer ..3620	Garton's .51 20 (46)
Red Fife.....18	Marquis...63⅓	Marquis....132	Marquis..4570	Red Fife .46 00
Marquis.....28	Garton's ..63 (46)	Garton's ...132 (46)	Red Fife .5060	Minn.....45 40
Minn. 169....38	Red Fife ..62½	Red Fife...132	Minn.169 5580	Pioneer ..36 00
Garton's.....60 (46)	Minn......60	Minn. 169. .139	Garton's .5600 (46)	Prelude ..28 20

TABLE No. 4

Average of Three Years' Notes on Rust as Observed on Varieties of Wheat, 1916, 1917, 1918

Amount of rust on straw on basis of 100 points	Weight of grain per measured bushel	Days maturing	Yield of straw per acre	Yield of grain per acre
	lbs.		lbs.	bus. lbs.
Prelude......17	Pioneer...61⅓	Prelude.... 98	Prelude ..2860	Marquis .41 00
Pioneer......23	Prelude...60¾	Pioneer....104	Pioneer ..3853	Garton's .37 40 (46)
Marquis.....38	Marquis...59½	Marquis....109	Marquis .4470	Pioneer ..34 50
Red Fife.....43	Garton's ..57 (46)	Garton's ...109 (46)	Garton's .5116 (46)	Red Fife .34 40
Minn. 169 ...49	Red Fife ..56¾	Red Fife ...112	Red Fife .5166	Minn.169 33 50
Garton's(46) .61	Minn. 169. 54	Minn. 169. .116	Minn.169 5507	Prelude ..26 30

It will be observed that Prelude, Pioneer and Marquis show the least damage by rust in all three years. Our observations lead us to believe that it is their earliness which is in a large measure responsible for their apparent resistance. We have observed that Prelude, although early maturing, is a variety very susceptible to rust. Each year rust has been observed first on this variety, although at the same date other varieties were still apparently free. This may be due to two causes, either that Prelude as a variety is more susceptible, or else, being earlier and further developed, it more quickly reaches the stage when the plant is a better medium for parasitic growth.

It is claimed by some writers that durum wheats are resistant to rust. The only variety of this type that we have been growing at the College has been the Kubanka. This variety has been selected for its milling quality and it may be that while selecting for milling value, the rust resistant qualities previously claimed for it have been sacrificed. Be this as it may, the variety has proved to be quite susceptible on the College plots and we would class it about the same as Red Fife.

It may be of interest to state that there are types of wheat which are more or less immune to rust. Despite the severity of rust attack in 1916, the Emmer and Einkorn wheats were bright of straw and practically free from disease, but as these are of no economic value to the western farmer, we mention them only as types which are apparently rust

resistant. At present we have no variety of milling wheat that is immune to rust, and while considerable work has been done in an endeavor to secure rust resistant strains, it has not given any degree of success up to date; one reason for this being that "rust years" do not come successively, but at uncertain intervals. Therefore, while Prelude and Pioneer stand high in the list in "rust years", in normal years their yield is so low that they cannot be grown profitably. On the other hand, Marquis has stood very close to these in the "rust year" and much above them at other times. On an average Marquis is the highest yielder and is the variety recommended for the wheat growing sections of Manitoba.

II.—EFFECT OF SUMMERFALLOWING AND FALL PLOWING OF LAND ON RUST IN THE SUCCEEDING CROP OF WHEAT

It is interesting to note the results of growing wheat on summerfallow and compare them with the results on fall plowed stubble land adjoining. During the summer of 1916 Marquis and Red Fife wheats were both sown on summerfallow and fall plowing, on the same date in May (on adjoining plots), with the following results:—

TABLE No. 5

	Yield per acre		Weight per bushel	Yield of straw	Amt. of rust on straw on basis of 100 points	Days maturing	Strength of straw on basis of 10 points
Marquis—	bus.	lbs.	lbs.	lbs.			
Fallow......	30	00	53	4,680	59	97–98	7
2nd crop....	27	50	58	3,390	45	97	9½
Red Fife—							
Fallow......	22	40	49½	5,700	59	99	7
2nd crop....	22	20	52	2,680	45	98	9½

In both cases the crop grown on fall plowed stubble land suffered less than the fallowed plots. It will also be noticed that the second crop produced less straw per acre and the proportion of grain to straw was:—

Marquis variety—

On fallowed plots the grain was to straw as 1 is to 2.6.
On fall plowed plots the grain was to straw as 1 is to 2.

Red Fife variety—

On fallowed plots the grain was to straw as 1 is to 4.2.
On fall plowed plots the grain was to straw as 1 is to 2.

The amount of rust was proportionate to the amount of straw produced. The same results were observed in the crop of 1917 and 1918. The heaviest strawed plots suffered the worst. The problem, then, with fallow land is to discover by what means of cultivation we can prevent soft and rank growth and induce a greater percentage of grain to straw.

Recommendations—Well worked and thorough summerfallows, though very productive of wheat in a normal year, are the worst for rust in a "rust year." **Where excessive heavy growth results from summerfallowing** it is necessary to take precautionary measures to ensure that the soil is compact. Such land should not be plowed deeply, as deep plowing tends to give rank growth of straw. Neither should such land be plowed twice the same season. The packer should follow the plow and every precaution be used to have the land firm. It is even sometimes advisable, when summerfallowing very thoroughly for the purpose of killing perennial weeds on land which predisposes to rank growth, to cultivate five or six times with the duckfoot cultivator and not to use the plow at all. Land cultivated in this way will not only be rid of the perennial weeds, but will produce a subsequent crop of wheat that is harder in the straw. The resulting amount of straw per acre is not usually so great as when the land is plowed, but the ratio of grain to straw is greater.

Another method of reducing the excessive "sappiness" on fallows is to sow some annual crop, such as oats and barley, in August or September. This should be sown thinly through every other drill of the seeder, and may be either pastured off in the fall, or allowed to grow until killed by the frost. This not only checks the excessive rankness of straw in the subsequent crop, and therefore would assist in rust control, but it also prevents drifting soil and is therefore doubly valuable.

III.—EFFECT OF DATE OF SEEDING UPON RUST

(Black Stem Rust)

There has been considerable discussion at various times as to the approximate date beyond which it is unwise to sow wheat. Seasonable variations are so wide that it is difficult to be specific and say which date is early and which is late. Earliness is a relative term and does not apply to the date, but rather to the earliness of the season when work on the land is possible. In 1916, the first date that it was possible to sow wheat was April 28th. On this date the first plot of the "Date of Seeding" experiment was sown on the College plots. The second plot was sown on May 5th and the successive seedings were continued every ten days until June 5th, after which seeding was done every fifth day until June 15th.

This experiment was conducted on both fallow and fall plowed stubble land with the following results:—

TABLE No. 6

Results of Dates of Seeding Wheat on Fallow, 1916

Variety—Marquis

Date sown	Yield per acre		Weight per bushel	Yield of straw	Amt. of rust on straw on basis of 100 points	Days maturing
	bus.	lbs.	lbs.	lbs.		
April 28	34	40	56	5,060	40%	104
May 5	30	40	54	5,100	45	99
May 16	19	20	53	3,880	50	91
May 27	10	40	43½	3,420	55	83
June 5	10	00	42	4,460	65	80
June 10	4	40	35½	3,420	70	76
June 15	1	40	32½	3,600	85	Not ripe

TABLE No. 7

Results of Dates of Seeding Wheat on Fall Plowing, 1916

Variety—Marquis

Date sown	Yield per acre		Weight per bushel	Yield of straw per acre	Amt. of rust on straw on basis of 100 points	Days maturing
	bus.	lbs.	lbs.	lbs.		
April 28	34	00	60	3,460	25	103
May 5	33	00	60	3,080	30	98
May 16	27	40	58	3,200	30	91
May 27	21	00	51½	3,400	45	83
June 5	10	00	45	2,500	55	80
June 10	3	20	37½	2,480	65	76
June 15	2	00	37½	3,300	85	Not ripe

In commenting upon the above tables, we draw attention to the fact that while decrease in quality and yield of grain results with the later seedings even in a normal year, considerable decrease in yield and quality directly chargeable to rust is shown in the above results. For instance, in the other years that the experiment had been running, good results have been obtained and grain of first quality secured from the first three dates of seeding. In 1916, however, there was a reduction in quality and yield after the first date and with each succeeding date of seeding, and wheat sown after May 15th suffered much more in proportion. The last plot sown on June 15th was worthless and was so eaten up with rust that the straw was rotten. It will also be noticed that wheat sown on May 27th on fall plowing gave a higher yield of grain of about the same quality than the wheat which was sown eleven days earlier on fallow land. The seeding on fall plowed land, sown May 27th, gave twice the yield of grain of the plot on summerfallow, sown on the same date. This experiment, backed by subsequent observation, shows that to lessen damage by rust, it is the best practice to sow the fallows first and the fall plowed land afterwards. A crop suffers more on summerfallowed land through delay

in seeding than does a delayed seeding on fall plowed land. It will be noticed that between the first and second seedings on "fallow" quoted above there was a decrease in quality of grain to the extent of two pounds per bushel, but between the first and second seedings on fall plowed land, we find that the quality of the grain was almost as good when sown on May 5th as the early seeding of April 28th. Both the latter seedings yielded grain weighing sixty pounds to the bushel, but the grading shows an advantage for the early sown plot, and not only so, but we obtained a bushel more per acre and had less rust on the straw.

Recommendations—Wheat on fallow should be sown earlier in the season than when the sowing is to be done after a stubble crop. On fallow, wheat should not be sown later than the second week in May. Wheat after a stubble crop may be sown later than after fallow, but not later than the second to the third week in May. If sown after May 10th on fallow and after May 15th on stubble land, wheat is very subject to rust. When it is not possible to sow before these dates some other crops such as flax, barley or oats will give greater returns per acre.

Caution re too early seeding—It should be pointed out that while we recommend early seeding to minimize rust damage, there may be the temptation to sow too early in an early spring. This harmful effect of too early seeding was clearly shown in the spring of 1918. Wheat was sown in some places so early that such crop had to be reseeded, and was later than if sown at the proper time, and consequently suffered worse from rust. It is not wise to sow wheat or any other cereal until the ground is warm enough to cause germination. It is seldom wise to sow wheat in Manitoba before the 10th to the 15th of April or later than the dates mentioned above.

IV.—EFFECT OF RATE OF SEEDING UPON BLACK STEM RUST OF WHEAT

We have been sowing Marquis wheat in an experiment to determine the rate of seeding advisable on Red River soils. Incidentally, some facts worth noting were observed with regard to the effect that the rate of seeding has upon the amount of rust upon the plants and damage done to the wheat crop. The various rates of seedings and effect of rust on weight per measured bushel, and amount of rust on the straw in 1916 are shown below. To compare the amount of damage directly chargeable to the rust, over and above the decrease in weight due to thin seeding, the average weights per measured bushel resulting in 1917 and 1918 are also included.

TABLE No. 8

Effect of Rate of Seeding Wheat on the Amount of Rust

Rate of seeding	Amt. of rust on straw on basis of 100 points	Weight per bushel, 1916	Average wt. per bushel, 1917 and 1918	Days maturing in 1916
		lbs.	lbs.	
¾ bus. per acre....	55	47¾	60¾	80
1 bus. per acre....	55	48	60¾	80
1¼ bus. per acre....	50	51½	61½	80
1½ bus. per acre....	50	53	61¾	79
1¾ bus. per acre....	45	53	61¾	79
2 bus. per acre....	40	52	62½	79

There were several conditions noticeable in the field which should also be mentioned in conjunction with the results shown in the table. Summarized these observations are as follows: Increase in the rate of seeding resulted in

1. Brighter and harder straw.
2. More freedom from rust.
3. Slightly earlier maturity.
4. Increase in weight.
5. Increase in yield per acre.

On the light seeded plots a rank straw was observed with considerable length of head, but, as the rate of seeding increased, the resulting straw was less rank and the length of the spike was reduced slightly with each successive increase in rate. When the grain on the plots seeded three-quarters to one bushel per acre was ripe, the straw was still green. This dead green color of straw after the grain is hard is a good indication of damage by rust. There was not so much difference in the actual date of ripening of the various plots, on account of the hot drying winds which came just before cutting time and ripened the grain prematurely. At the time of infection by spring spores, however, there was much more difference in the stage of maturity.

Our observations of this experiment were continued in 1917 and 1918 and it was observed that the conclusion reached above held good in both years. The degree of decrease in grain and weight due to thin seeding and the number of rust pustules on the straw were more in evidence in 1916, but the same general deduction held good in the subsequent years.

This experiment indicates that the crop must be sown sufficiently thick **on this heavy soil** to prevent rank growth. The sowing of wheat thinly induces conditions in the plant similar to those caused by summer-fallowed land namely:—

1. Rankness of straw.
2. Delayed maturity.
3. Lack of hardiness (that is the light seeded plants were not as hardy as were the plants on heavier seeded plots which covered the ground properly).

Recommendations—Wheat on fallows should be sown thicker than after a stubble crop. Judgment on this point is necessary, but somewhere

around 1¾ to 2 bushels per acre is better than the old hard and fast rule of 1½ bushels per acre. On fallows which grow exceptionally rank straw 2¼ bushels should be sown.

The rate of seeding wheat after a stubble crop recommended is from 1¼ to 1¾ bushels depending upon whether the soil is light or heavy. In sections where it is necessary to hasten maturity, 1½ to 1¾ bushels per acre should be used On lighter land which is not rich and where early maturity is not such an important factor, the lighter rates of seeding will give greater returns and from 1¼ to 1½ bushels should be sown.

V.—EFFECT OF HARROWING THE GROWING GRAIN AND ITS RELATION TO RUST

In 1916 there were no experiments conducted on the College plots with the harrowing of wheat after it was above the ground, but in 1917 an experiment was conducted to note the effect of harrowing wheat and the following results were obtained. It may be mentioned that the wheat was sown on fallow and before harrowing the plots were very uniform. There was considerable rust in evidence on the wheat on the harrowed plots as shown in the following table:—

TABLE No. 9

Showing the Damage Done by Rust to Wheat which was Harrowed while Growing

Treatment	Yield per acre		Weight per measured bushel	Yield of straw per acre	Amt. of rust on straw on basis of 100 points	Days maturing
	bus.	lbs.	lbs.	lbs.		
Not harrowed	36	00	61	3,680	20	106
Harrowed coming up	33	00	59	4,100	35	108
Harrowed 2″ high	30	40	58½	4,240	35	108
Harrowed 4″ high	30	40	58	3,980	35	108
Harrowed 6″ high	31	20	57½	3,560	40	108
Harrowed coming up and 6″ high	21	40	53½	3,240	55	110

We notice that harrowing the growing grain brings about two conditions:—

1st Maturity is delayed.
2nd A thinning out of the plants and a ranker growth of the remaining plants.

Both of these factors we have seen have a direct bearing upon reducing the vitality of wheat and increasing the susceptibility to rust. It will be noticed also that on the plots which were harrowed twice, the amount of rust was considerably more than on the plots which were harrowed only once.

Recommendations—The conclusions drawn from the experiment, in so far as it affects rust, are that the land should be put in good tilth before seeding and any subsequent harrowing should be done before the grain is above ground, so as not to retard the grain; especially should harrowing grain be discountenanced when the presence of trash crop residue or roots would drag out an excessive quantity of grain by gathering on the harrows, resulting in a thin crop which would by reason of ranker growth, be more severely attacked by rust than an even crop which covered the ground properly.

The practice of harrowing growing grain is followed as an aid in weed control and in past years has proved very efficient in combating certain weeds. If the loss from rust continues, our aim then should be to utilize some of the other methods of weed control so that the necessity of harrowing growing grain will be done away with.

VI.—THE EFFECT OF MANURING UPON WHEAT RUST

We have already seen that cultural methods produce modification of the physical nature of wheat plants, rendering them more or less susceptible to rust attack.

The results of an experiment re the effect of applications of barnyard manure on the following wheat crop throws further light on the question of rust susceptibility. In this experiment the manure was applied to corn stubble land in the fall of 1915 and fall plowed, followed with a crop of wheat the succeeding year (1916).

In 1917 wheat was sown again and all plots were about equally affected by a slight attack of rust. The attack in this year (1917) was only slight, however, and increase of yield was secured on the manured over the unmanured plots without injury from rust being aggravated. This would indicate that the increase of rust is greater if a "rust year" follows immediately after the application of manure and that the detrimental effects are not lasting. The immediate effects, however, are severe as shown by injury done by rust to wheat in 1916 that was manured in the fall of 1915. It should be borne in mind, in studying the table of results, that the experiment was conducted on Red River clay soil, which contained a high percentage of humus. By bearing in mind the nature of the soil, we can better interpret the following results:—

TABLE No. 10

Effects (on Susceptibility to Rust) of Applying Rotted Barynard Manure Direct to Wheat

Amount applied previous fall	Yield of grain		Weight per bushel	Amt. of rust apparent on straw on basis of 100 points	Days maturing
	bus.	lbs.	lbs.		
None	21	20	52½	50	80
3 tons per acre	21	00	50½	50	80
6 tons per acre	18	40	48	65	81
9 tons per acre	12	00	47	65	81

In addition to the above table, notes taken in the field show that the heads of wheat on the various plots were gradually tapered and the length of fertile head shortened with each additional increase of manure; and also that the increase in rate of manuring induced a greater number of infertile spikelets in the head or spike, and the condition known as "White Tip" was the result.

With these undesirable features there was also on the heavier manured plots a very pronounced weakness of straw, more lodging, delayed maturity and consequently more rust.

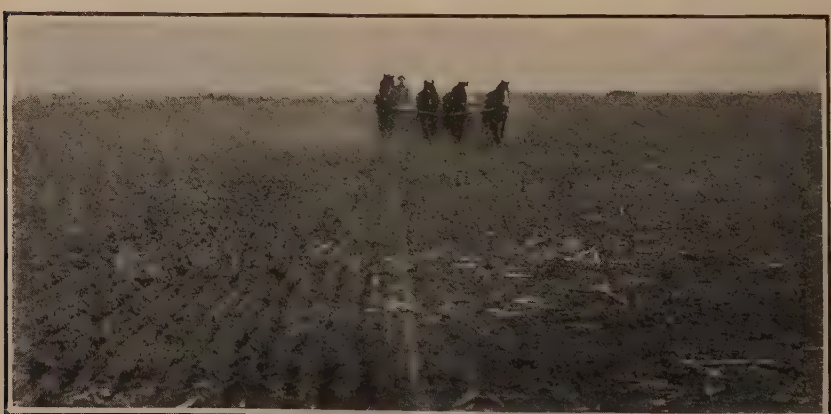
It will be noticed that the above harmful effects were the result of applying manure direct to the wheat crop. These effects were not noticeable when the manure was applied indirectly. For instance, another plot was manured at the rate of ten tons per acre early in the season of 1915 and the plot subsequently planted to corn. After fodder corn in the fall of that season, it was also plowed and prepared for wheat with the following results:—

TABLE No. 11

Rotted Manure (Barnyard) Applied for Corn Crop, 1915 and the Plot Sown to Wheat in 1916

	Yield per acre	Weight per Bushel	Days maturing
	bus. lbs.	lbs.	
Wheat, 1916..................	24 00	55	79

This plot showed considerably less rust than did the plots where the manure was applied direct to the wheat crop. This may be explained by assuming that the application of manure produced an excess of nitrates in a soil already rich in humus. By growing corn upon this land, the excess of nitrates was profitably used to produce a class of forage in which succulence and increased vegetable growth are desired. Thus the excess of nitrates was removed and the chemical constituents of the soil better



Sowing wheat on disked corn stubble results in stiffer straw than is produced where wheat is sown after fallow, and yields a crop that is less susceptible to rust.

balanced for the succeeding crop of wheat, in the production of which heavy straw is not desired. From the following table, taken from Hopkins' "Soil Fertility" (pages 154 and 157), it is evident that we can make a soil too rich in nitrogen for profitable wheat production, even with moderate applications of manure, if applied to a soil which already contains sufficient soluble plant food for crop requirements.

TABLE No. 12

	Nitrogen	Phosphorous	Potassium
A crop of wheat yielding 25 bushels per acre removes from the soil approximately..	48 lbs.	8 lbs.	29 lbs.
1 ton of fresh barnyard manure contains approximately......................	10 lbs.	2 lbs.	8 lbs.
1 ton of rotten barnyard manure contains approximately......................	10 lbs.	3 lbs.	8 lbs.
10 tons of rotten barnyard manure contains approximately......................	100 lbs.	30 lbs.	80 lbs.

A twenty-five bushel crop of wheat, therefore, requires roughly about as much nitrogen, phosphorous and potassium as is contained in four or five tons of barnyard manure. The soil, however, is never so deficient, even in long farmed soils, that it is depleted of these elements. It should be borne in mind that an application of manure lasts several years and that only a small quantity is weathered and made available each year, yet it will be seen from table No. 12 that it is quite easy to apply manure so heavily that nitrogen will be added in larger quantities than is required by the wheat crop, and unbalanced growth would result. Nitrogen is important in plant development. Its absence from the soil will result in a yellow, sickly looking crop. Abundance of nitrogen will result in an excessive growth of dark green foliage, increased succulence and abundance of straw; and too much succulence in the wheat plant results in a more severe attack by rust.

Comes, Orazio, in Publications, International Agricultural Institute, Volume 3, No. 9, Page 52, shows that "the abundance or otherwise of nitrogen affects the wheat plant both physically and chemically. Physi-

Manure causes rank growth of vegetation. Corn uses the excess nitrates applied in barnyard manure. Succulent growth is secured in the corn crop, where succulence is required, and the soil is left in a better balanced condition for a crop of wheat.

cally the excess of nitrogen stimulates the cell activity of plants and causes the cells to increase in size and number with a simultaneous decrease in the thickness of the cell walls. Chemically the cell sap is changed and becomes less acid. That is to say, the acidity of cell sap in unmanured plants is greater than in the manured plants. With decrease in acidity there entails high starch production and consequent increase in sugars. Liquids containing sugar are the best medium for the development of mycelium of fungi."

We see, then, that manuring too heavily produces excess of nitrogen in the soil, which results in increased damage when the plants are attacked by rust because:—

1st. The plant is less hardy, more succulent and more susceptible to infection.
2nd. The cell sap of the plant becomes a better medium for the development of the parasite.

Other factors will bring about similar conditions. For instance, a well worked field of summerfallow on rich land will often contain an excess of soluble nitrates, and a rank, lodged straw, badly attacked by rust will result. It is probable that the reason for the rankness of straw and the susceptibility to rust is the same on both the manured and the fallowed land, the difference being that in the first case the source of excess of nitrates in the soil is the manure, and in the latter case the source is the nitrification of the organic matter in the soil during the time the land lay fallow.

The above statements should not be taken to imply that manuring should be discontinued, but they are offered in explanation of why it is that rust strikes badly on highly manured fields. Indeed, from a cultural standpoint, many soils in the Province would be greatly benefited by the judicious application of manure to prevent drifting and to increase the water-holding capacity of light soils and also improve heavy soils by increasing the porosity and improving drainage.

It is a common practice in the west to spread manure much too thick. The writer has frequently seen fields which had applications of at least from twenty to twenty-five tons per acre, which is much more than is generally needed from a fertility standpoint, and very undesirable from the standpoint of rust control.

Recommendations for Applying Manure

The proper time to apply manure in the rotation is before corn or roots, or as a top dressing to the grass crop. In these crops rank growth is desired and wheat sown after either a manured, cultivated crop, or after manured sod broken and backset, will not only be profitable in any year but will not suffer so readily from rust in a rust year as when sown after fallow. Manure applied to summer-fallow only makes the following wheat crop more susceptible to rust. If applied, however, to summer-fallow, the best time to apply it is as a thin top dressing to the wheat to prevent soil drifting in the spring. Where land is new and fairly rich, manure, if applied to wheat after a stubble crop, should be applied very sparingly and thoroughly and uniformly spread, preferably with a manure spreader.

VII.—UNIFORM DEPTH OF SEEDING AND ITS RELATION TO RUST

The importance of depth of seeding to secure uniformity of germination and uniformity of crop is well known. In 1916 we found that lack of uniformity of depth of seeding had quite a marked influence on rust development. This conclusion was reached as the result of observations of a field which showed this feature to a marked degree. The field was spring plowed, and, owing to unfavorable weather conditions and imperfect drainage, the seed bed was not as uniform as was desired. Consequently, the depth of seeding was not uniform and quite a large percentage of the seeds did not germinate until several days after the remainder had taken root. The plants from these seeds were much behind the others in growth all the season. When the crop should have been ripe these plants were green and immature. Moreover, they were considerably more rusted than the balance of the crop. In the season of 1917 we observed similar results. The spring was so dry that on some of the plots which were plowed the previous fall we found it very difficult to work up a fine seed bed. Consequently, germination was retarded and very uneven. The wheat sown on these plots contained much second growth, which became badly rusted later in the season. On the plots which contained more moisture and were in better tilth, germination was uniform and the crop uniform, without the "second growth" so apparent in other plots. "Second growth" is very subject to rust and may be compared to crop sown late (see date of seeding experiment, page 9), and is not only a source of loss in any year, but aggravates the damage in a year when rust is prevalent. It should be our object, then, to put the soil in such tilth that we can secure uniformity of seed bed and uniformity in depth of seeding, which will result in uniform germination and uniform development. This will help to eliminate some of the conditions of soil which retard and delay growth early in the season and which bring about that belated condition in which the plant is unable to resist the attacks of rust.

VIII.—EFFECT OF DRIFTING SOIL ON SUSCEPTIBILITY TO RUST

During 1918 the unusually high winds caused the soil in Manitoba to drift more than in any previous year under observation. Not only was much crop blown out and other crop set back, but also it was noticed that fields that had drifted badly in the spring were badly rusted. The effect on the crop was similar to that from thin and late seeding. Drifting soil, in retarding a crop and thinning it out, becomes a factor in predisposing to rust. As a preventive measure summerfallow liable to drift should be sown with an annual crop in the late summer as outlined on page 8 and the resulting growth left to hold the surface soil from drifting. This will give temporary relief, but provision should be made to seed down to brome grass and alfalfa or sweet clover. This will correct the lack of fibre in the soil, and as wheat after breaking is less subject to rust than after a bare fallow, seeding down will help indirectly in rust control.

IX.—WEEDS IN THEIR RELATION TO RUST

Weeds play quite an important part in the increase in liability to rust attack. We have noticed that wheat fields which have a large quantity of weeds suffer very considerably and have more rust upon the straw than fields which are free from weeds. This is explained by several conditions:

1. The weeds, by increasing the vegetation and presenting larger leaf areas than the wheat plants alone, hold more moisture during and subsequent to the muggy, damp weather which usually occurs at the time of infection, thus giving a humid condition which favors spore germination and rust development.

2. Weeds transpire large quantities of water, which assists the dew in keeping the plants moist.

3. By covering and shading the ground and filling in between the drills of grain, weeds prevent free circulation of air and the penetration of the sun's rays, which would dry the wheat plants more rapidly if the weeds were absent.

Thus, by increasing vegetation, assisting in humidity and shading the lower part of the crop, ideal conditions are produced for spore germination. When the spores are carried to such fields they readily adhere to the damp leaves and germinate freely; and, moreover, light rains do not wash the spores off to any great extent, but only aggravate the undesirable humid conditions.

The above statements, however, refer to weeds in a crop on rich strong moist soil, such as a weedy summerfallow. It is frequently noticed that on very weedy fields there is less rust on the straw and the grain is fairly plump. Where this latter condition is in evidence it usually results from the fact that the crop is sown on stubble land that is lacking in soil moisture. The cause is a dry soil condition, resulting in a hard growth of straw, rather than the presence of weeds, the crop, by virtue of the soil condition, being comparatively free from rust in spite of weeds. Thus what would be a poor weedy crop in a rust free year occasionally produces the best sample of grain in a rust year (see Section II, Page 8).

X.—PLUMP SEED AND RUST

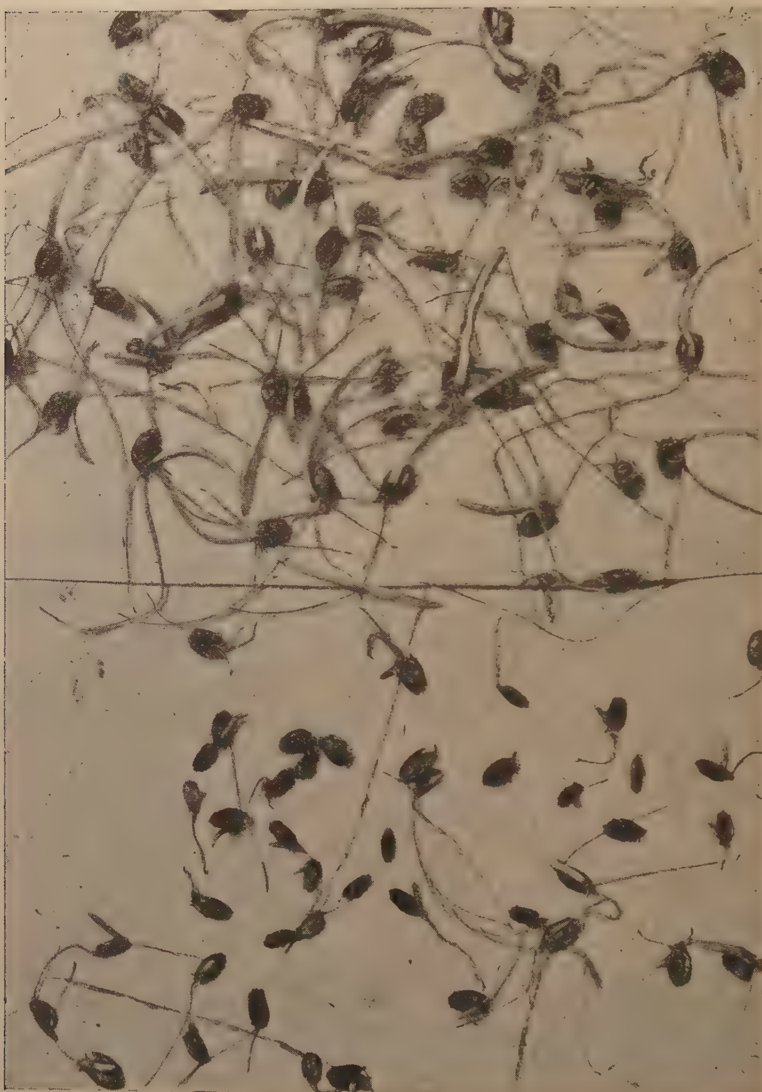
Plump seed should be sown so that the young wheat plants may have an abundance of plant food to tide them over the critical period of growth in the early spring. As we have pointed out, if a crop gets a setback early in its growth (as when harrowed after it is above ground) it will not mature as early as if it did not get that setback, and will be more subject to rust

attack. Good plump seed will, therefore, assist as an aid to rust control in stimulating a young crop of wheat after adverse weather conditions. A young crop from light weight seed will not recover so readily if badly frozen back early in the season and the result is consequent lateness of crop. Under adverse conditions it may even be necessary to reseed, as was the case with some crops in 1918, and the lateness of an injured or reseeded crop predisposes to rust.

The same number of seeds were sown in each of these pots, and the treatment was in every way exactly the same. The difference in growth arises entirely from the fact that the plants in the left hand pot grew from strong, plump seeds, and those in the other pot from very shrivelled seeds. Not only did the good seed produce more plants, but these began to grow quicker and were very much more vigorous.

Should Rusted Wheat Be Sown for Seed ?

It is considered quite safe to sow rusted wheat for seed as far as danger of infection of the resulting crop is concerned, as a study of the life history of wheat rust will show. Good plump seed graded from a rusted crop is preferable to that from non-rusted crop, as it shows the ability to mature and withstand injury from rust attack. Small shrunken seeds, however, should be screened out, because while they may germinate a high percentage, the resulting plants will be of reduced vitality. If well graded up it is, therefore, good practice to sow wheat from a rusted crop if it is the best seed available. (See Circular No. 38, by J. H. Bridge, B.S.A., Manitoba Agricultural College.)



The difference in strength of sprouts from plump, well matured seeds and rusted, shrivelled seeds is shown herewith. The seeds above and below the black line were germinated on separate blotters under exactly the same conditions. Almost every grain in the lower rusted sample shows a small sprout, but germination in the upper lot of seeds was so much faster that the sprouts were an inch long by the time the shrivelled seed had commenced to grow. Such differences as these are characteristic.

XI.—SUBSTITUTING OTHER CROPS

Where wheat rust becomes severe and persists year by year, it is recommended that some other crop which is not subject to rust should be grown instead of wheat. Rye is an example of such a crop. Winter rye is fairly hardy in most places in Manitoba and will produce profitable crops and is not subject to wheat rust. The following straw crops may be used as substitutes: winter rye, flax, spring rye, oats and barley may be made to give profitable returns where wheat production is handicapped by constant and severe attacks of black stem-rust.

Winter rye grows rapidly and may be cut early. This photo, taken at the Manitoba Agricultural College Farm on July 4th, 1916, shows the winter rye to be five feet six inches high. The seed was sown Sept. 1st, 1915. This crop yielded 50 bus. and 40 lbs. per acre.

XII.—DRAINAGE

Large undrained areas, such as marshes, etc., near wheat fields are productive of a heavy humid atmosphere during damp, muggy weather. This is a condition in which wheat rust makes the most rapid growth and which makes a crop more susceptible by keeping it damp. It is recommended that undrained areas in wheat growing sections be drained as an aid to rust control. "Pot holes" in a field are also injurious. Not only are they annoying because of the fact that they make it less economical to work such fields, but the delay they cause in seeding and the slow or retarded germination and backward crop on the baked soil that frequently results when they dry up, may be responsible for a field being more affected by rust.

These "pot holes" should be surface drained to run off the surface water early in the spring and the result will not only be beneficial from a good farming standpoint, but will also lessen in a measure the liability to rust of a crop which is grown on them.

"Pot holes" result in injured soil conditions, late seeding, and subsequent liability to rust attack.

XIII—EFFECT OF CUTTING RUSTED WHEAT AT VARIOUS STAGES OF MATURITY

The question of the best time to cut a rusted wheat crop has been a somewhat debatable one. Popular opinion is that when wheat is attacked by rust it is better to cut it on the green side than to delay cutting, as it is generally assumed that rusted grain will lose weight if left until ripe before being cut. The following experiment, conducted on the College plots in 1918, indicates that the grain should not be cut at a stage before it would be harvested in the ordinary course of events if rust were absent, and that the maximum weight is secured in cutting when the grain cannot be crushed when subject to pressure between thumb and finger.

Two fields of badly rusted Marquis wheat were divided into plots and cut at various stages of maturity. The results on both fields were the same. Cutting was commenced on the first plot in each field when the grain was in the late milk stage, and each succeeding plot was cut three days later than the preceding one (except when unfavorable weather made it necessary to postpone cutting until the first day that it was fit to operate the binder).

The following results are submitted:

Date Cut	Stage of maturity of grain	Weight per measured bushel (average of both fields)
July 24	Late milk	56
July 29	Early dough	58¼
Aug. 1	Late dough	58½
Aug. 4	*Firm	59
Aug. 11	Dead ripe	58¾
Aug. 14	Dead ripe	58¼

* The wheat was adjudged "firm," when it could not be crushed when subject to pressure between thumb and finger (see plot 4).

The following general observations regarding the resulting grain were also noted:

Premature cutting resulted in—
1. Brighter color and lustre.
2. Many shrunken grains of a bright brick red color.
3. Considerable numbers of green immature kernels.
4. Shrunken berries and decreased weight.

Cutting when the grain was firm resulted in—
1. The greatest weight per bushel.
2. The greatest yields.
3. The best quality of grain.

Cutting delayed until the grain was dead ripe resulted in—
1. Lack of lustre.
2. Bleaching of the grain.
3. Slight loss of weight.
4. Slightly reduced yields, due partially to shelling of the best grain and partialyl to drying.

CONCLUSION

In reviewing the situation with regard to rust at the present time, we would point out that while considerable investigational work has been done in various countries in an endeavor to solve the problem of wheat rust, and while much has been discovered that is of interest, yet from the practical standpoint of reducing, controlling or preventing the damage little has been achieved. Scientific investigators have given us the knowledge of the disease, its form, nature, characteristics and life history, but there yet remains to be discovered the methods of control. Most of the work that has been done along this line has been done in endeavoring to secure, by selection, a type or variety of wheat which will be rust resistant. As we have pointed out in the foregoing pages, this type or variety of spring wheat is not yet in the hands of the western farmer.

Though we cannot prevent rust, yet we can in a measure control some of the factors which predispose to rust and intensify the injury. We therefore submit that if the precautions recommended are carried out, the resulting crop will not suffer so severely in a year of rust attack, and if we reduce the damage by only one bushel per acre we will have saved the Province several million dollars.

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